frequency measurement of aluminium beam with multiple cracks

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Under the Guidance of
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CERTIFICATE

This is to certify that the thesis entitled, **"frequency measurement of aluminium beam with multiple cracks"** submitted by **Balabhadra Marndi** in partial fulfilment for the requirements for the award of Bachelor of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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Abstract

It has been observed that the dynamic behaviour of a structure changes due to the presence of a crack. Analysis of such phenomena is useful for fault diagnosis and the detection of cracks in structures. An experimental setup is designed in which an aluminium cantilever beam with two cracks is excited by a hammer and accelerometer attached to the beam provides the response. The cracks are assumed to be open to avoid non-linearity. The effects of crack ratios and positions on the fundamental frequencies of slender cantilever beams with two edge cracks are investigated experimentally and compared with numerical results obtained using a finite element code. The experiments are conducted using specimens having edge cracks of different depths at different positions to validate the numerical results obtained. Fourteen numbers of beams having crack depth 2mm, 4mm with the variation in location of 2^{nd} crack are taken to perform the experiment. The experimental results of frequencies can be obtained from Fast Fourier Transform (FFT) analyzer. The numerical results are shown to be in good agreement with the experimental results for the considered crack ratios.

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Chapter 1

I N T R O D U C T I O N

1. Introduction

The behaviour of members of structure varies as per damaged or undamaged condition. Most of structures fail due to damage like cracks in member. So, many experiments are done to know the dynamic behaviour of members. The cracks cause the reduction in stiffness and natural frequency. In this paper the objective is to get the natural frequency of cantilever beam with multiple cracks which alert from resonance of structure which leads to fail. And also verify the frequency with the experimental and analytical value.

Aluminium is widely used in aircrafts and machinery structures. Because of vibration and cyclic loading action it get cracks on it. This leads to the change in natural frequencies of member. This experiment is done to know the effect of crack characteristics (depth, location, number of cracks) on the natural frequencies of beam.

The experimental results of frequencies are compared with the numerical results of frequencies using Finite element code. The experimental frequency can be obtained from PULSE software using Fast Fourier Transform analyzer.

Chapter 2

LITERATURE REVIEW

2. History and literature review

Many experiments have been done to study to know the dynamic behaviour of cracked beam. Chondros and Dimarogonas[1] analysed on effect of crack on a structure by comparing the signal in frequency and time domain: and concluded that, increase in crack depth results the increase in amplitude of vibration. Secondly, the amplitude of low frequency vibration decreases and high frequency vibration increases when the location of crack is increased. Ertugrul Cam, Sadettin Orhan, Murat Luy[2] (2004) studied on cracked beam to obtain the location of crack and depth. For this, the signals of non-defected and defected are compared in the frequency domain. The software ANSYS was good to obtain the experimental and simulations. Brad A. Butrym[3] explored to identify the minimum crack depth by vibration method by using the Structural Health Monitoring. And second thing to determine the life span of damaged beam once the impedance method determine the damage. D.P. Patil, S.K. Maiti[4] verified on experimental results of natural frequencies for slender cantilever beam. Energy method was used to analyse and crack was represented by rotational spring. The crack size was computed from relation between stiffness and crack size. They concluded that the maximum error of predicting position of crack get reduced with an increase in number of cracks. E.Douka and L.J. Hadjileontiadis[5] concluded that the mean variation of the Instantaneous Frequency(IF) increases with crack depth, following a second order polynomial law.

Chapter 3
EXPERIMENTATION

3.1 APPARATUS REQUIRED

- Modal hammer
- Accelerometer
- FFT Analyser
- Display unit(laptop)
- Specimen

3.2 APPARATUS DESCRIPTION

3.2.1 Deltatron Accelerometer (B & K4507):

Deltatron accelerometer have high and low sensitivity and small physical dimensions. So it is ideally suitable for the experiment. It is easily fitted to different test objects using adhesive. It is shown in Fig. 3.1

Fig. 3.1 Deltatron accelerometer

3.2.2 Modal hammer (B&K 2302-5)

The modal hammer exist the structure with a constant force over a frequency range of interest. Three interchange tips are provided which determine the width of the input pulse and thus the band width the hammer structure is acceleration compensated to avoid glitches in the spectrum due to hammer structure resonance. It is shown in Fig. 3.2

Fig. 3.2 Modal hammer

3.2.3 Portable FFT Analyzer (B & K 3560C)

Bruel and kjaer pulse analyzer system type – 3560. The software analysis was used to measure the frequency ranges to which the foundation various machines are subjected to when the machine is running with no load and full load. This will help us in designing the foundations of various machines on such a way that they are able to resist the vibration caused in them. It is shown in Fig. 3.3

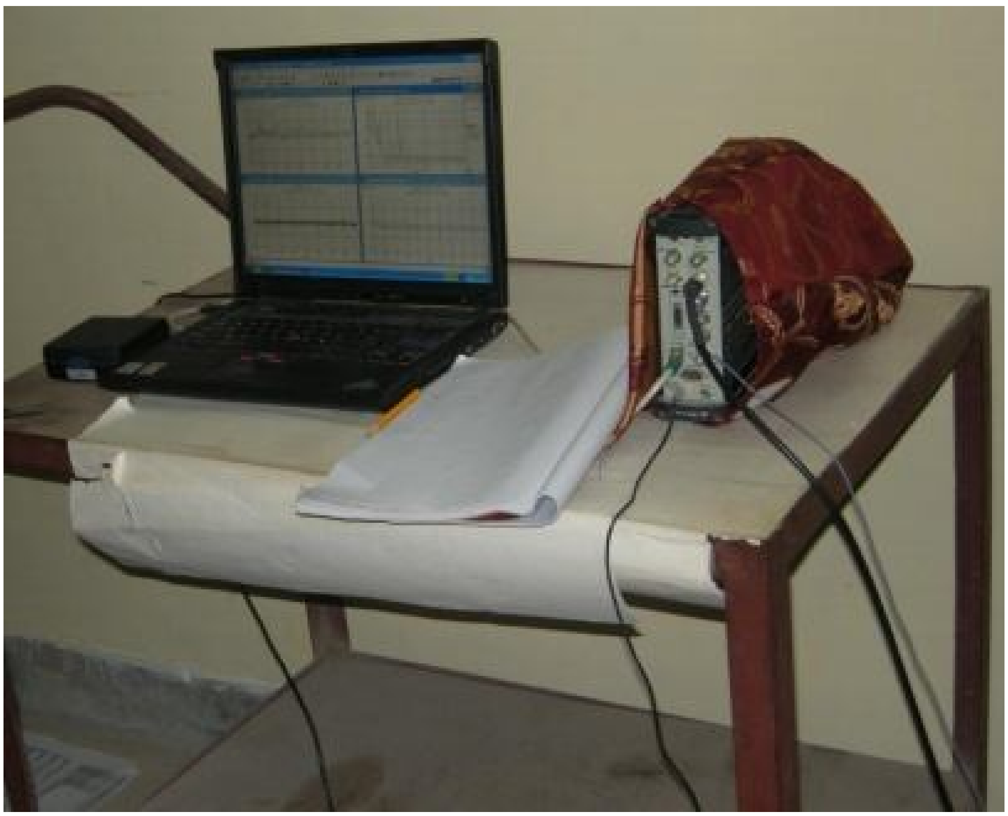

Fig. 3.3 Portable FFT analyzer (B & K 3560)

3.2.4 Display unit

This is mainly in the form of PC (Laptop) when the excitation occurs to the structure the signals transferred to the portable PULSE and after conversion comes in graphical form through the software. Mainly the data includes graphs of force Vs time, frequency Vs time resonance frequency data etc. It is displayed in Fig. 3.4

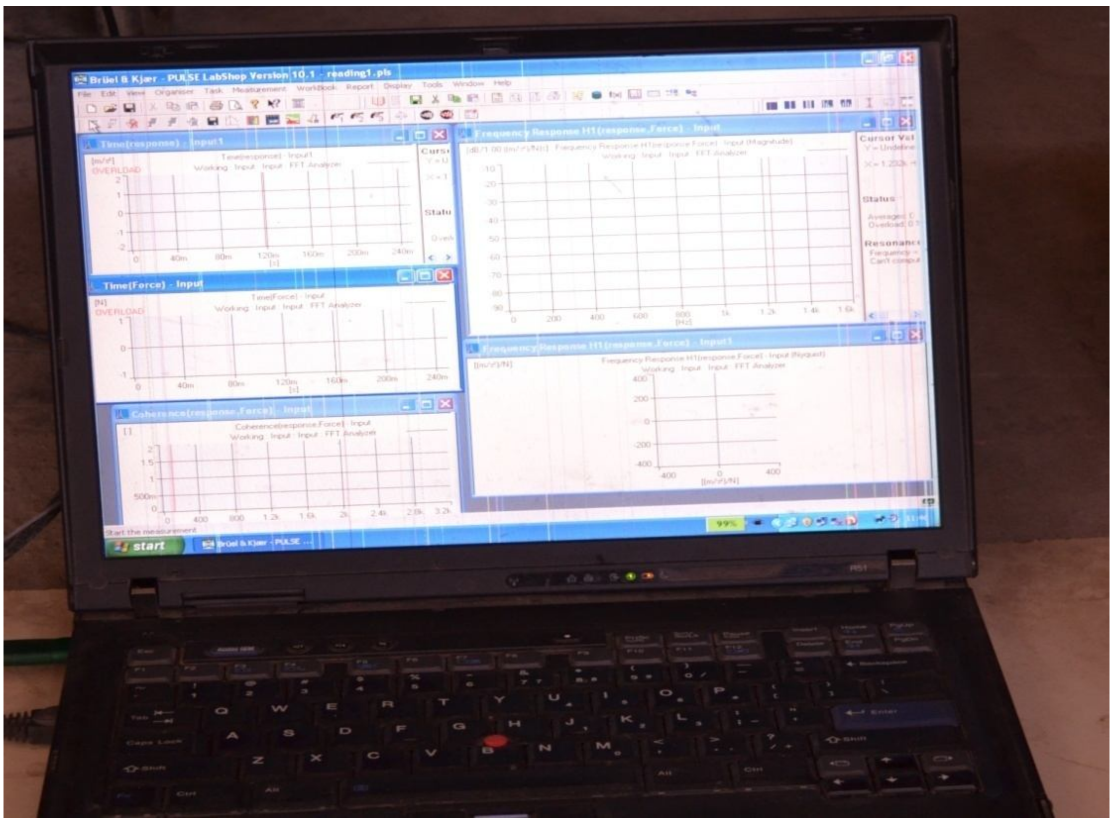

Fig. 3.4 Display unit

3.2.5 Specimen

Beam specification: Effective length (L)= 32.2cm

Breadth= 0.9cm

Depth= 0.9cm

Modulus of Elasticity of aluminium beam (E) = 70Gpa

Density of aluminium beam (ρ) =2700kg/m3

Poisson’s ratio (μ) = 0.28

3.3 Preparation of specimen

The aluminium beams are cut out from the available long beam and transverse cracks were developed on it.

- The effective length of beam is 32.2cm on clamping it on one end.
- A crack of depth 2mm made at a distance of 3cm from fixed end
- Keeping the position of 1st crack constant, make another crack of depth 2mm at 6cm,9cm,12cm,15cm from fixed end
- A crack of depth 4mm is developed at distance of 3cm from fixed end.
- Keeping the position of 1st crack constant and a depth 4mm, make another crack of depth 2mm at 6cm,9cm,12cm,15cm from fixed end
- Keeping the position of 1st crack constant and depth 4mm, make another crack of depth 4mm at 6cm,9cm,12cm,15cm from fixed end
- Total 14 numbers of specimens are prepared to perform the experiment
- Locations of cracks on specimen are shown in Fig. 3.4
- Beam specification are shown in the Fig. 3.5

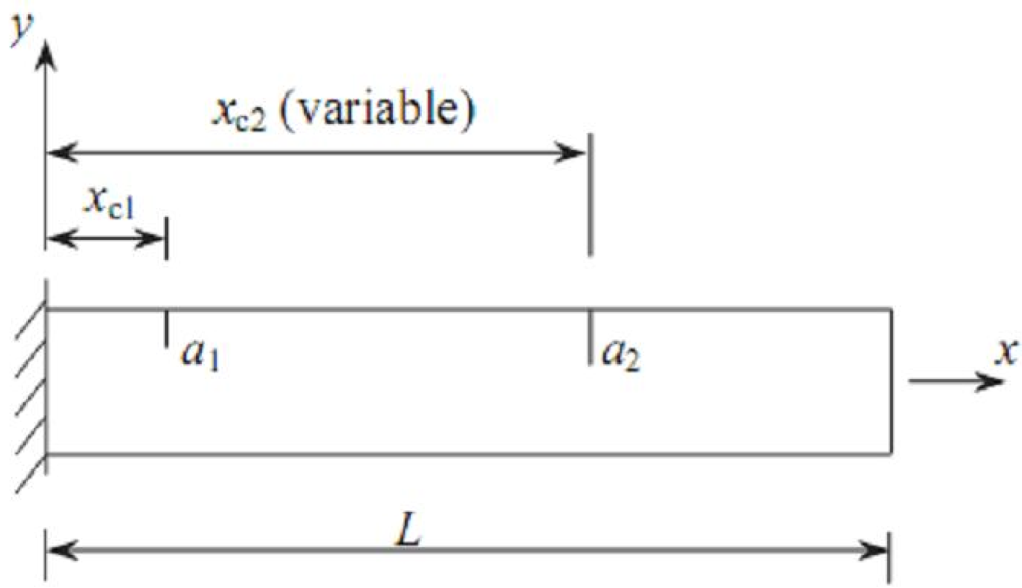

Fig. 3.4 Fig. 3.4 schematic diagram for location of cracks in specimen

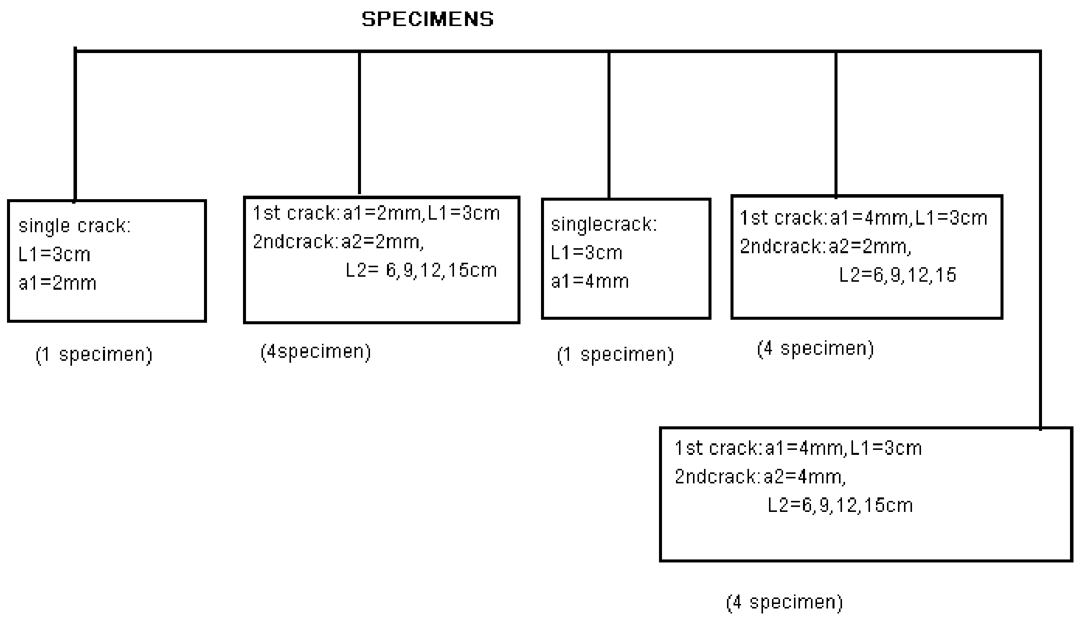

Fig 3.5 Beam or specimen specification (depth,location)

3.4 Experimental Setup

- A aluminium beam of is cut out from the available long baem.
- To make it cantilever structure it is clamped at one end by bolting it.
- To perform the experiment the Deltatron accelerometer is attached and exited by modal hammer.
- The Deltatron accelerometer and modal hammer are connected to the Bruel & Kajaer.
- The Bruel and Kajaer instrument is connected to the display unit having the PULSE software.
- The vibration in beam is transformed to the graphical representation in frequency domain and displayed at the laptop. The graph for frequency from PULSE software is shown in Fig 3.6
- The 1^{st} ,2^{nd},3^{rd} peak values of graph are considered as 1^{st},2^{nd},3^{rd}mode of frequency

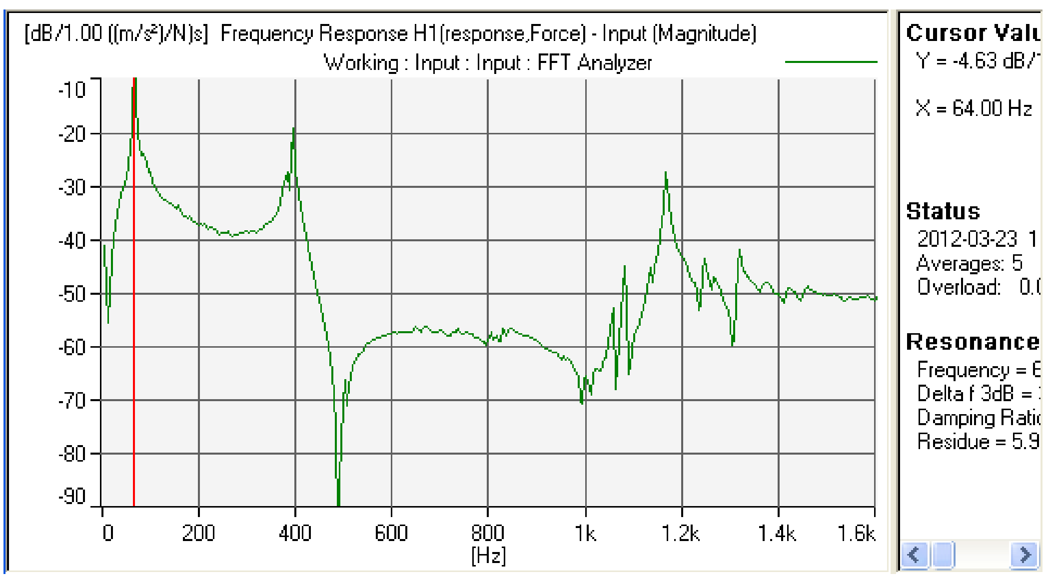

Fig. 3.6 graph for frequency from PULSE software

Fig. 3.7 laboratory setup for cantilever beam

3.5 Procedure

- A notch is made on an aluminium beam at a distance of 3cm from one end and a depth of 2mm and the crack is perpendicular to any of two axis of beam.

- To make it cantilever structure, the beam is clamped by bolting at one side.

- The effective length(L) changes to 32.2cm and $X(L_1)$= 3cm

- Using adhesive the deltatron accelerometer is attached on the beam and a small load is applied on beam by striking it slowly.

- It was hammered for 5 times. It is the avarage value.

- A heavy sruck will show “Overload” on the display unit and the software will not count the any further strike there after.

- Continue the above procedure to get accurate value.

Chapter 4

RESULTS AND DISCUSSIONS

4.1 Frequency measurement of single cracked beam

Table 4.1 Observations for 1st Specimen (S1) having (a1=2mm, L1=3m)

Sl no	**1st mode(Hz) (computational=69.92) (W1)**	**2nd mode(Hz) (computational=442.77) (W2)**	**3rd mode(Hz) (computational =1243.02)(W3)**
1	64	396	1172
2	64	396	1168
3	64	396	1172

Table 4.2 Observations for 2nd Specimen (S2) having (a1=4mm, L1=3m)

Sl no	**1st mode(Hz) (computational=65.05)**	**2nd mode(Hz) (computational=431.81)**	**3rd mode(Hz) (computational=1235.2)**
1	64	392	1244
2	64	392	1244
3	64	392	1244

Change in natural frequency with the change in depth of crack can be verified using the current results. It is shown in the Fig. 4.1

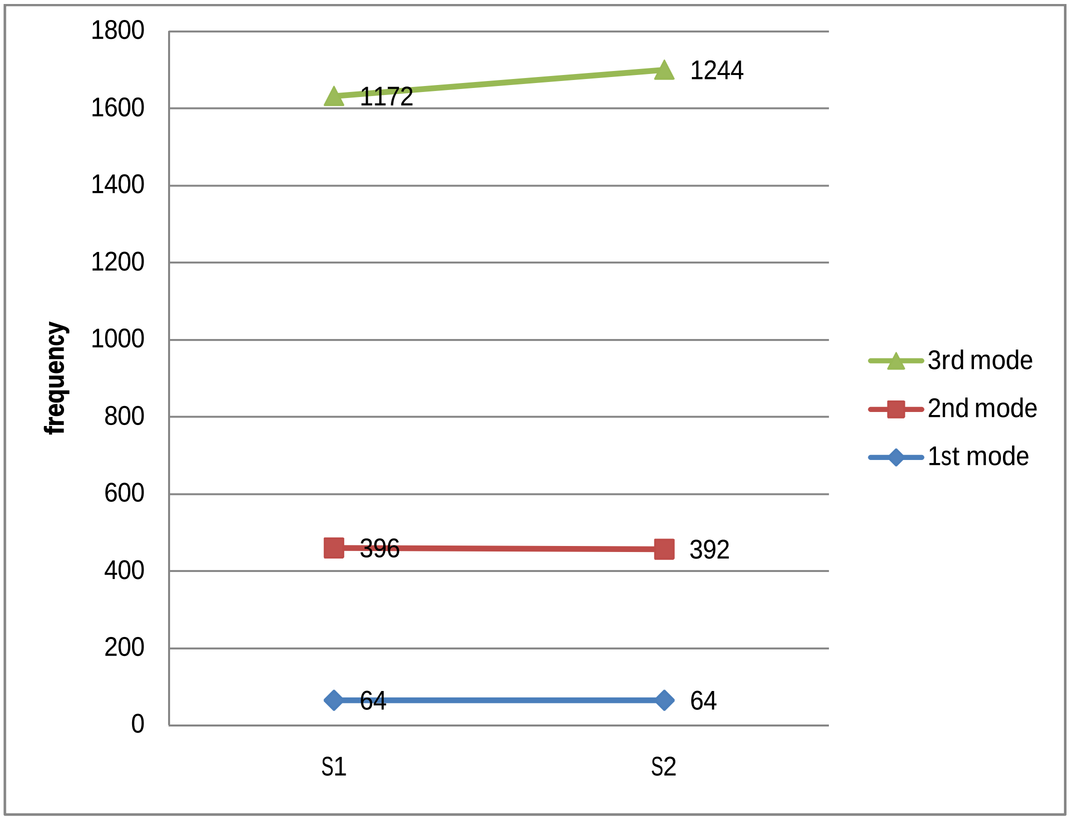

Fig. 4.1 Frequencies of single crack with 2mm and 4mm depth

4.2 Frequency measurement of double cracked beam

The figure below is the actual setup in laboratory. Here one end is fixed and both the cracks are open and the accelerometer is fixed by adhesive. Here, distance of 2nd crack (L2) from fixed end is variable, which changes 6, 9,12,15cm from fixed end. It is as per the experimental requirement.

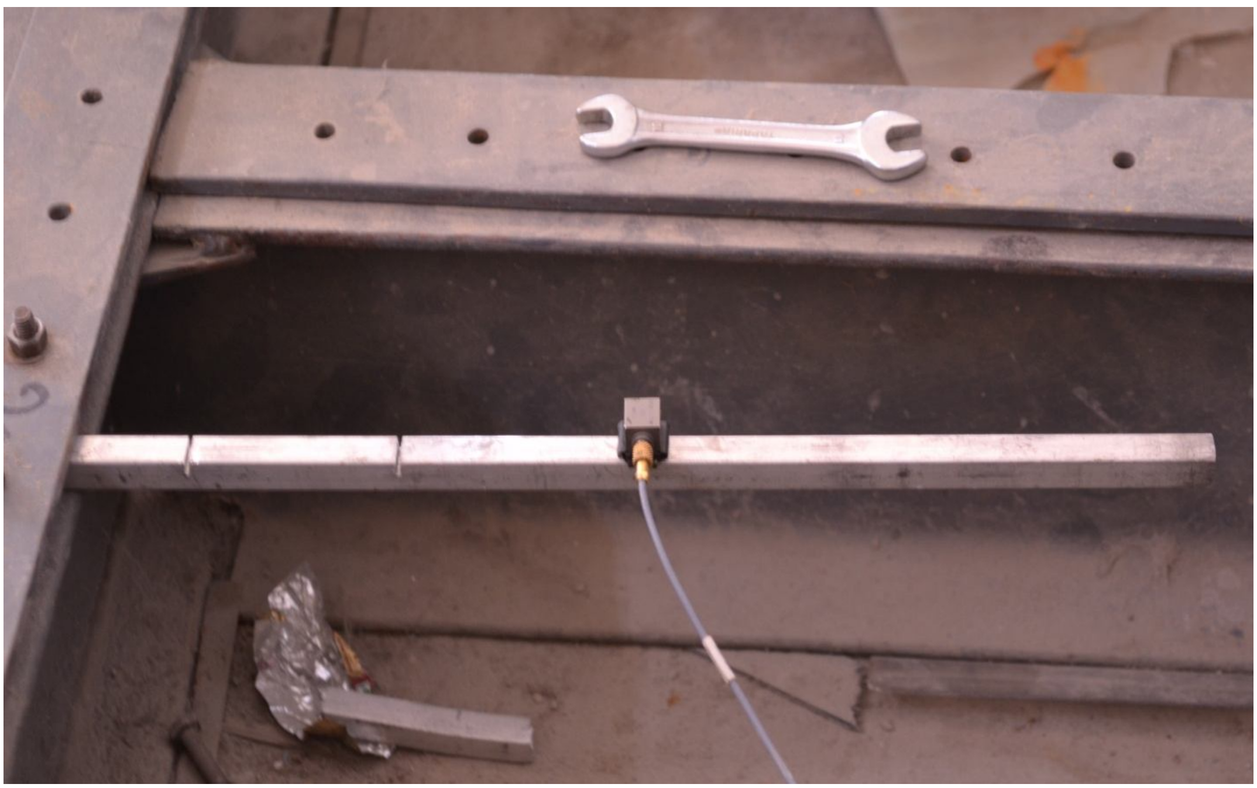

Fig. 4.2 Laboratory set up of double cracked beam

Table 4.3 Observations for 3rd Specimen (S3) having (a1=2mm, a2=2mm, L1=3m, L2=6cm)

Sl no	**1st mode(Hz) (computational=67.92)**	**2nd mode(Hz) (computational=442.48)**	**3rd mode(Hz) (computational=1234.96)**
1	64	376	1172
2	64	376	1176
3	64	392	1172

Table 4.4 Observations for 4th Specimen (S4) having (a1=2mm, a2=2mm L1=3m, L2=9cm)

Sl no	**1st mode(Hz) (computational=68.53)**	**2nd mode(Hz) (computational=441.31)**	**3rd mode(Hz) (computational=1216.95)**
1	64	368	1184
2	64	368	1184
3	64	372	1184

Table 4.5 Observations for 5th Specimen (S5) having (a1=2mm, a2=2mm L1=3m, L2=12cm)

Sl no	1st mode(Hz) (computational =69.01)	2nd mode(Hz) (computational =435.80)	3rd mode(Hz) (computational =1222.04)
1	68	396	1196
2 T	68	396	1192
3	68	392	1196

Table 4.6 Observations for 6th Specimen (S6) having (a1=2mm, a2=2mm L1=3m, L2=15cm)

Sl no	1st mode(Hz) (computational =69.38)	2nd mode(Hz) (computational =431.56)	3rd mode(Hz) (computational =1242.40)
1	68	408	1236
2	68	408	1236
3	68	408	1236

From previous results of frequencies of all four (S3, S4, S5, S6) specimens, a graph can be plotted to know the variations in modes of vibration. The position of second crack is changed and moved away from the fixed end and the depths of cracks are 2mm.

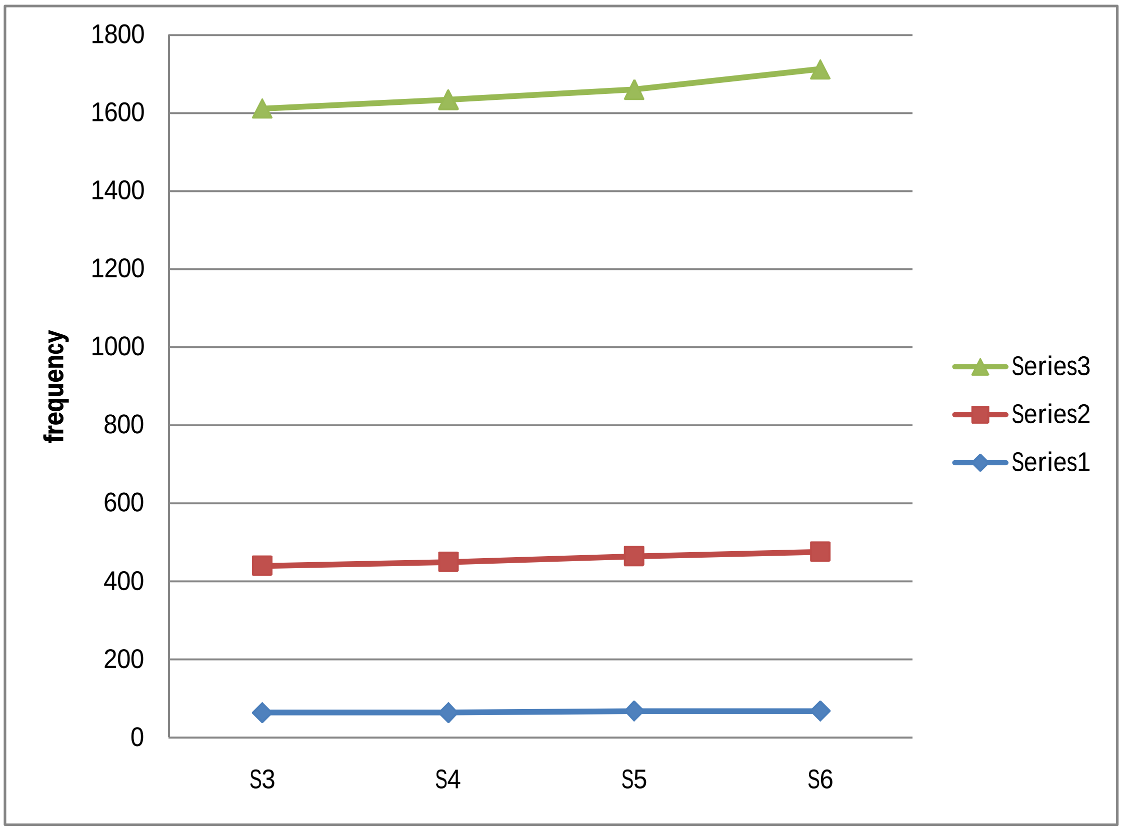

Fig 4.3 variation of frequency with change in L2 and a1=a2=2mm

Table 4.7 Observations for 7th Specimen (S7) having (a1=4mm, a2=4mm, L1=3m, L2=6cm)

Sl no	**1st mode(Hz) (computational =58.23)**	**2nd mode(Hz) (computational =430.715)**	**3rd mode(Hz) (computational =1191.41)**
1	52	340	1180
2	52	344	1180
3	52	340	1180

Table 4.8 Observations for 8th Specimen (S8) having (a1=4mm, a2=4mm, L1=3m, L2=9cm)

Sl no	**1st mode(Hz) (computational =60.132)**	**2nd mode(Hz) (computational =422.692)**	**3rd mode(Hz) (computational =1132.1)**
1	52	340	1132
2	52	344	1132
3	52	340	1132

Table 4.9 Observations for 9th Specimen (S9); (a1=4mm, a2=4mm, L1=3m, L2=12cm)

Sl no	1st mode(Hz) (computational =61.74)	2nd mode(Hz) (computational =400.498)	3rdmode(Hz) (computational =1157.52)
1	56	340	1136
2	56	340	1136
3	56	340	1136

Table 4.10 Observations for 10th Specimen (S10); (a1=4mm, a2=4mm, L1=3m, L2=15cm)

Sl no	1st mode(Hz) (computational =63.05)	2nd mode(Hz) (computational =385.91)	3rd mode(Hz) (computational =1230.13)
1	60	336	1184
2	60	336	1184
3	60	336	1184

Table 4.11 Variation of frequency with the change in depth of crack of double cracked beam

Depth of crack(mm)	L1=3cm,L2=6cm			L1=3cm,L2=9cm		
	W1	**W2**	**W3**	**W1**	**W2**	**W3**
2	64	376	1172	64	368	1184
4	52	340	1180	52	344	1132

Depth of crack(mm)	L1=3cm,L2=15cm			L1=3cm,L2=12cm		
	W1	**W2**	**W3**	**W1**	**W2**	**W3**
2	68	408	1236	68	408	1196
4	60	336	1184	56	340	1136

1st mode: W1, 2nd mode: W2, 3rd mode: W3

A graph is plotted to know the behaviour of frequencies of double cracked beams, having the crack depths of 2mm and 4mm. The distance of 1st crack from fixed end (L1) =3cm and distance of 2nd crack from fixed end (L2) = 9cm.

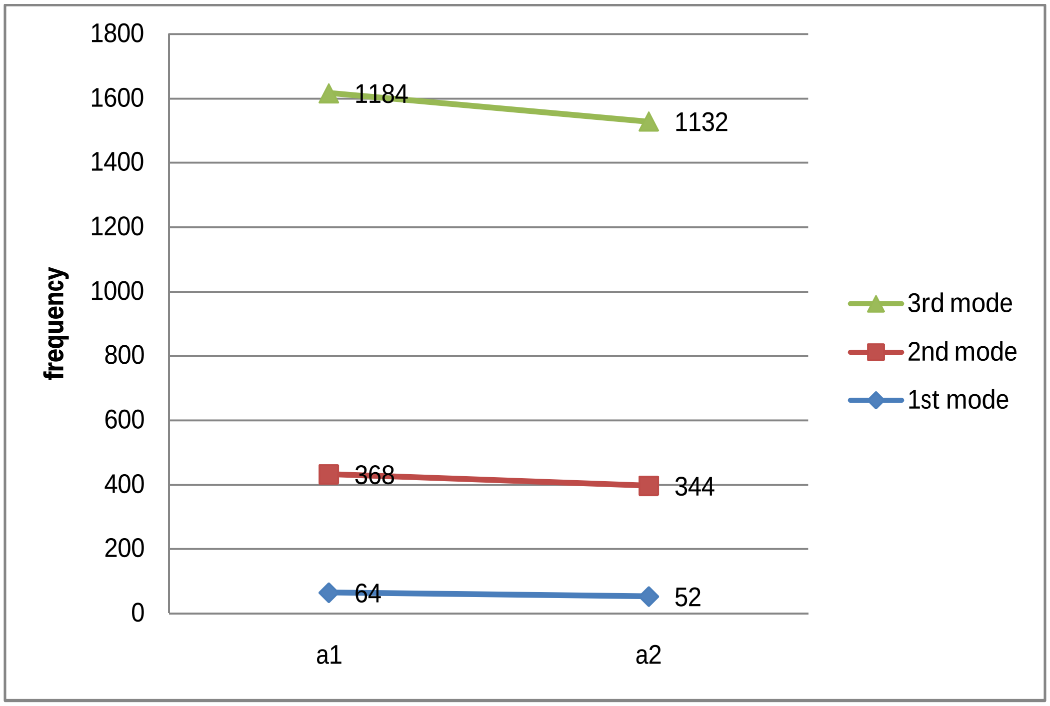

Fig. 4.4 variation of frequency with change in crack depth

Table 4.12 change in frequency with change in number of crack

No of crack	Crack of depth 2mm			Crack of depth 4mm		
	W1	**W2**	**W3**	**W1**	**W2**	**W3**
1	64	396	1172	64	392	1244
2	56	376	1172	52	340	1180

A graph is plotted between frequency vs nuumber of cracks. Here the comparison of is done between the beams having equal depth of cracks (4mm) and having the number of cracks= 1 and 2.

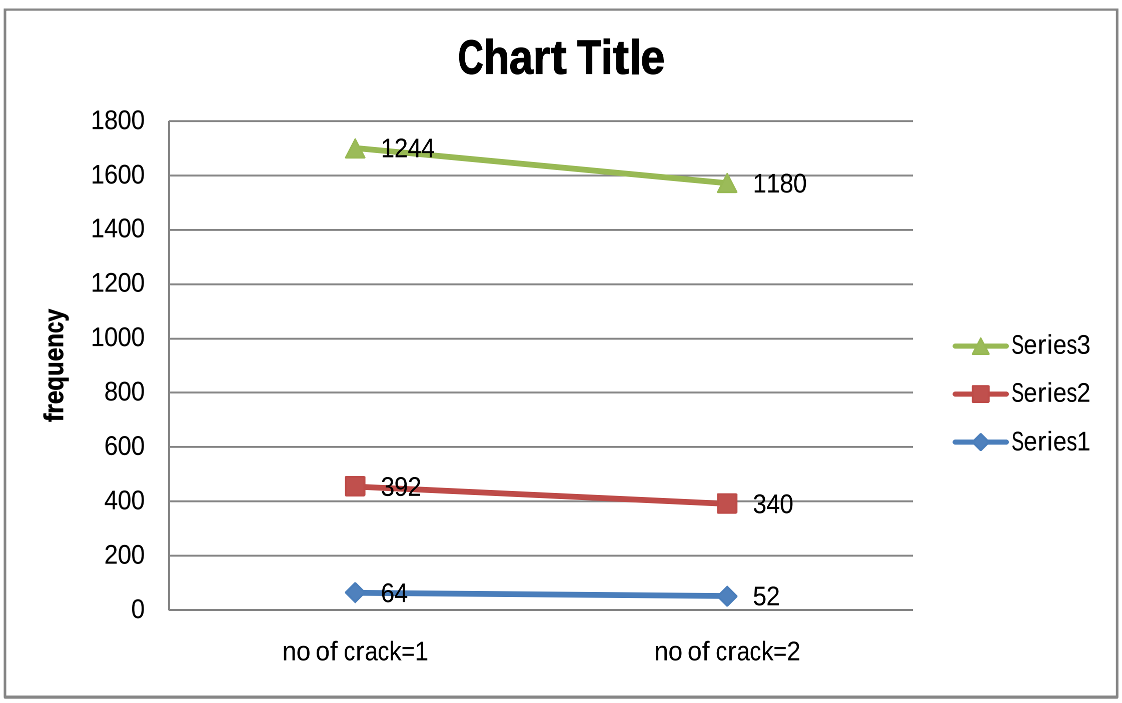

Fig 4.5 change in frequency with change in number of crack

Table 4.13 Observations for 11thSpecimen (S11) having (a1=4mm, a2=2mm, L1=3m, L2=6cm)

Sl no	**1st mode(Hz) (computational =60.66)**	**2nd mode(Hz) (computational =430.78)**	**3rd mode(Hz) (computational =1205.1)**
1	60	368	1204
2	60	368	1204
3	60	360	1204

Table 4.14 Observations for 12thSpecimen (S12) having (a1=4mm, a2=2mm, L1=3m, L2=9cm)

Sl no	**1st mode(Hz) (computational =61.94)**	**2nd mode(Hz) (computational =426.03)**	**3rd mode(Hz) (computational =1165.72)**
1	56	364	1208
2	56	364	1208
3	56	364	1208

Table 4.15 Observations for 13th Specimen (S13) having (a1=4mm, a2=2mm, L1=3m, L2=12cm)

Sl no	**1st mode(Hz) (computational =62.993)**	**2nd mode(Hz) (computational =411.33)**	**3rd mode(Hz) (computational =1182.038)**
1	56	396	1196
2	56	396	1196
3	56	396	1196

Table 4.16 Observations for 14th Specimen(S14); (a1=4mm, a2=2mm, L1=3m, L2=15cm)

Sl no	**1st mode(Hz) (computational =63.828)**	**2nd mode(Hz) (computational =401.679)**	**3rd mode(Hz) (computational =1232.51038)**
1	52	396	1232.518
2	52	400	1232.518
3	52	400	1232.518

Table 4.17 Change in frequency with the change in relative depth

Sl no	1^{st} mode(Hz)	2^{nd} mode(Hz)	3^{rd} mode(Hz)
(S4) Both the craks of 2mm depth L1=3cm,L2=6cm	64	376	1172
(S12)1^{st} crack=4mm, 2^{nd}crack=2mm L1=3cm,L2=6cm	60	368	1204
(S8)Both the craks of 4mm L1=3cm,L2=6cm	52	340	1180

To know the behaviour of frequency, when the depth of 2^{nd} crack is gradually increased at a particular position and by keeping the position and crack depth same for 1^{st} crack.

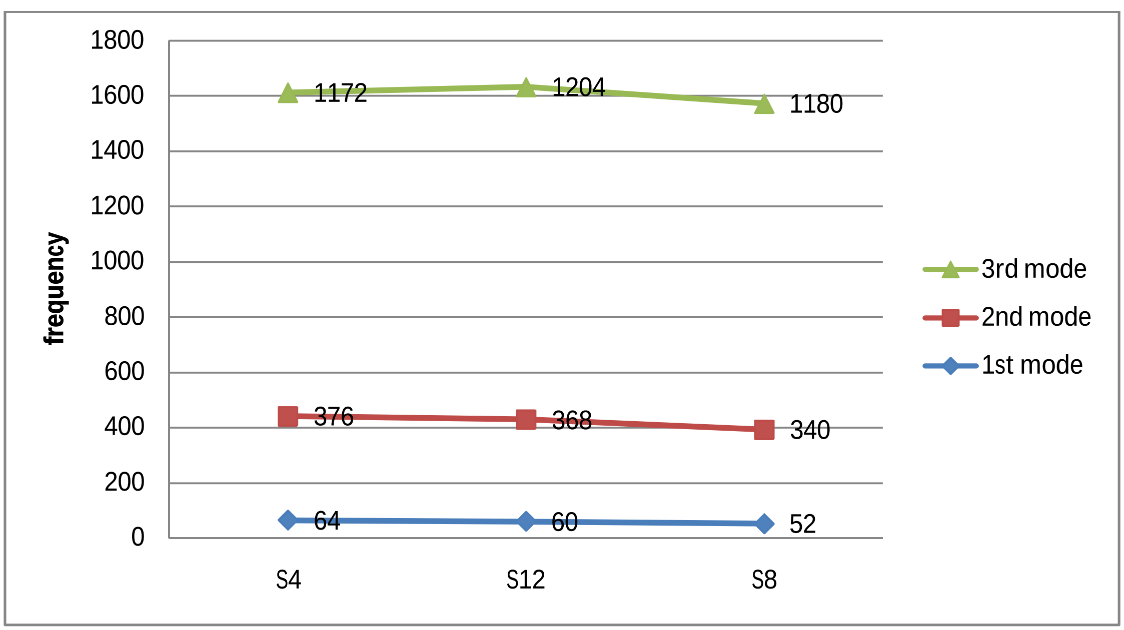

Fig. 4.5 Change in frequency with change in relative depth at certain location of cracks

Chapter 5
CONCLUSION

5. CONCLUSION

- The frequencies of vibration of cracked beams decrease with increase in the depth of crack for crack at particular location.
- The natural frequencies of a cantilever cracked beam decreases with increase in the number of cracks.
- The frequencies decrease with increase in the relative depth of cracks at particular location of cracks.
- The effect of crack is more pronounced when the cracks are near to the fixed end than at free end. Multiple cracks near the fixed end makes the beam more flexible than the same number of cracks at the free end of same intensity.

Chapter 6
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